Opto-Smart Pet Feeder

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***Abstract* — The Opto-Smart pet feeder is a new type of pet feeder that employs the use of both optics and electronics to automatically feed the users pets when they are not around. This system works by identifying monochromatic light sources that are received by a camera in the feeder, allowing food to automatically dispense. This eliminates the worry of pets being neglected.**

***Index Terms* — Color imaging, Electronic circuits, Infrared detectors, Image processing, Microcontrollers, Microcomputers.**

I. Introduction

There are many different types of pet feeders on the market today, but few employ the use of electronics to automatically dispense pet food and most of those products rely on simple timers and can only serve one pet at a time. With many people going back to the office after the COVID-19 pandemic, pets around the world are suffering due to a sudden change to their everyday dietary routine. This product helps eliminate the time, energy, and stress put on the pet owners to feed their pets while they're away from home. Using optics and electronics, the device ensures that the owner's pets are being routinely fed with their correct pet food, without the pet owner being physically present with them. Devices that autonomously feed pets do already exist, however, the use of optics to better ensure that the pets are routinely fed with the proper pet food is what differentiates our product from others that are already on the market today.

The Opto-Smart Pet Feeder contains two main and separate parts to properly feed the user's pets. The first main component is the tag on the collar the user's pets must always wear.

The tag on the collar that is initially described functions as a pet specific identification tag for the feeder to read and acknowledge to dispense the pet food for that specific pet. To do this, an LED light that is embedded inside of the tag's water-resistant plastic container emits a specific color of light that the pet feeder can recognize and dispense the correct pet food for that specific pet. This function is especially useful for houses with more than one pet, as the user's second and third pets can wear a collar tag that emits a different color of light than a color that is already in use to properly distinguish and recognize to dispense the pet food for that specific pet accordingly.

The second main component is the autonomous feeder that dispenses the pet's food. The pet feeder contains a compact camera inside the feeding system that monitors and searches the area for the predetermined color of light that is illuminating from the tag on the pet's collar. The user can further decide the specific time of day in which the pet feeder can scan and detect the light coming from the tag on the pet's collar. At that specific time of set by the user on the online application, the pet feeder will dispense the appropriately set amount of pet food into the corresponding pet's bowl. Once the food has been dispensed to the pet's bowl, the correct lid will open, when the corresponding LED is sensed, allowing the pet to eat its food from the bowl. Infrared LED's surrounding the bowl will constantly be providing the photodiodes as a signal. Once the pet begins eating from the bowl, the photodiodes will be blocked, causing the lid to remain open until the pet completely removes its head from the bowl. Once the detectors regain the signal from the infrared LEDs, a countdown to close the bowl begins. If something does not block the signal within the time the user selects, the lid will properly close automatically.

For the device to properly function and to fully accomplish all tasks mentioned above, several lines of functions and methods in code must be written and implemented into the microcontroller embedded inside the system. The code executed and complied into the microcontroller must be written well enough for the pet feeder to be able to correctly identify and distinguish if the selected color of LED light shining from the tag attached to the pet's collar exists in the camera's point of view. Once the correct color of LED light is recognized and acknowledged by the system code in the microcontroller, the dispenser will release the proper pet food for the corresponding pet to eat. The written code must also dispense the accurate amount of food the users decide to feed for that specific pet. The code implemented will allow the user to enter in their exact feeding time.

II. SUBSYSTEMS

2.1 IMAGE DETECTION

The camera system will constantly be monitoring the area in front of the Opto-Smart pet feeder. When it identifies the designated bright LED, it will recognize the assigned dog that is trying to eat based off the color of the LED. Seeing the assigned color will activate the system to start the process of opening the lid.

The camera system that we will use will consist of a compact webcam that will fit inside of the feeder housing and record the environment and look for a specific color. This device will operate just as well in low light environments as environments with regular ambient lighting. This is due to the target being observed emitting its own light source.

The camera will individually scan each row of pixels looking for a specific RGB value that is unique to each collar tag. Technology like this is useful in several different fields. From defense products in planes and missiles to industrial machine lines for packaging and consumer level applications like in toys and smart devices. This is a useful feature that can operate efficiently with nothing but off the shelf components and code. As you can see below, in figure 1 our system is able to scan an image looking for a certain color and then identify the specified color.

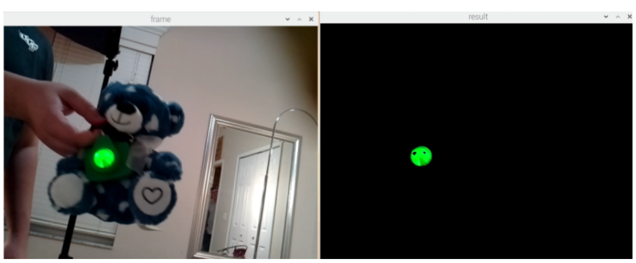

Fig. 1: Color Detection

2.1.1 RASPBERRY PI

The Raspberry Pi 4 microprocessor has all the necessary capabilities and functionality to have our device reach its fullest potential. With the Raspberry Pi 4 microprocessor basically being a microcomputer, the Raspberry Pi 4 can and will for our case replace a traditional desktop within the system as the microprocessor takes in all inputs related to a traditional desktop such as a power supply, HDMI, keyboard, and mouse, with proper WIFI, and ethernet control making the possibilities of the Raspberry Pi 4 practically endless.

Specifically for our project, the Raspberry Pi 4 will act as the brains of our device operation allowing the system to dissect logic with the implemented Python code, especially when we plug in a compatible camera input into the Raspberry Pi 4 and allow for the camera to detect the LED light attached to the collar of the pet to further determine whether or not the color of the LED light is correct (true), and ultimately open the lid properly for the animal to eat the food by activating the Arduino.

2.1.2 RASPBERRY PI CAMERA

The camera that was chosen was a Jun-Electron 5 MP, 1080P Video Camera Module that is compatible with the Raspberry Pi. It also came with a camera case to house the camera, to help prevent it from getting damaged. This compact camera is 3.15 x 2.76 inches, which is compact enough to fit within our design. Since it supports 1080P it allows us to have a high-resolution camera that is able to properly integrate into our design.

2.2 COLLAR TAG

This is a device that accompanies the Opto-Smart Pet feeder the pet wears so that the camera system will be able to detect the pet. The tag itself is a 3D printed plastic shell that is small enough to not get in the way of the pets' daily functions. The final 3D printed collar can be seen below in figure 2.

Fig. 2: Collar Tag

2.2.1 PCB

The main PCB for our device was developed for power regulation of the electrical hardware as well as motor control of the two motors that will be utilized within the system. To power the microcontroller, microprocessor, and IR LEDs, regulated voltages will be delivered by this PCB to their desired components. Featured on this PCB are two voltage regulator circuits that utilize a 12V input and output a constant 5V and 7 V, respectively. The L293D motor driver IC on the PCB will be used to power and control two DC motors.

Both voltage regulator circuits are designed using LM2576 switching regulators that allow for more efficiency over most linear counterparts. The 5V output will be used to power the Raspberry Pi microprocessor, while the 7V output will be used to power the Arduino microcontroller. The 5V output will also be utilized to power the logic inside the L293D chip, and the 12V power from the input of the board will power both motors within the system.

In addition to the main power PCB, three additional collar PCBs were developed to power a colored (red, green, or blue) LED that will be present on the pet's collar. The collar PCB to be implemented within the pet collar is a relatively small circuit board that can deliver power to an LED so that the chosen camera module can detect the color emitted from the LED. This collar PCB is approximately 34.5 mm x 48.3 mm to easily and securely fit within the casing that will be constructed for the pet collar. With this constraint in mind, the battery size must also be small enough to fit on the collar PCB without causing and conflicts with the surrounding casing, which is why we chose a CR1632 battery.

Our collar PCB is comprised of a 3V Battery, a 220 Ohm, 125-ohm Resistor, a color LED, and an on off switch. Our Red LED has a central wavelength of 630 nm, the green LED has a central wavelength of 525 nm, and the blue LED is 470 nm.

The software that was used to design the main PCB and collar PCB was Easy EDA, since it is a fully functional software that allows both schematic and PCB creation. A quality PCB is crucial for the Opto-Smart Pet Feeder not only for peak performance but to ensure a long lifetime for the product.

2.2.2 Lens System

A lens will allow the collar tag to be seen by the feeder's camera system at a greater distance since the light from the LED is being dispersed. The lens will also act as protection for the internal components of the system. It will allow us to operate the LED at a lower power level, which helps us conserve energy. This feature will also help ensure eye safety as the light will be dispersed and will not be as bright if viewed directly.

A planoconvex lens is one of the most common type of lens used in optics. It is a lens that has one flat surface and one curved surface that allows for light to be focused, collected, and collimated. The two surfaces of the planoconvex lens work together by focusing parallel light rays to a focal point.

Planoconvex lenses can be designed to have either long or short focal lengths to manipulate where an image forms and the magnification of the image. For the Opto-Smart Pet Feeder having a short focal length in the image plane is advantageous since allows for light emitted by the LED to diverge from the lens and enable the camera system to identify the LED color more easily from a greater distance and a larger angle.

The N-BK7 Plano-Convex Lens we chose has a focal length of 25 mm and a 1-inch diameter. The Zemax tracing for this lens is shown in Figure 3. Since this lens will be used for three different wavelengths no AR coatings are necessary.

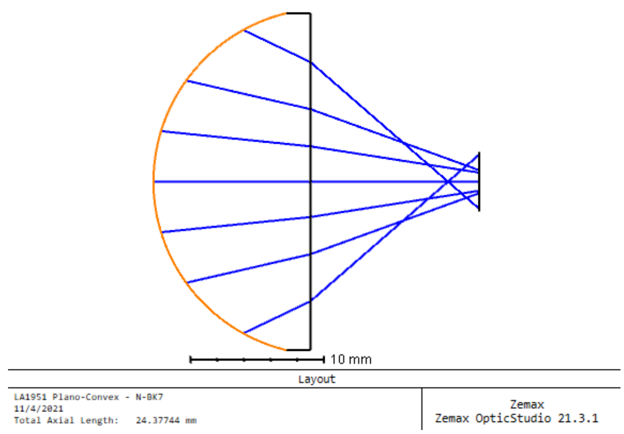

Fig. 3 Zemax illustration of lens used

2.3 Object Detection / Automatic Opening and Closing Lid

This system consists of a motorized plastic lid that sits over the top of the object detection system, the food dispensing chute, and the pet bowl.

2.3.1 IR LED and Photodiodes

The Opto-Smart pet bowl team have chosen to use an IR LED that will emit light at or around 950 nm. This wavelength was chosen due to its abundant use in many electronic devices such as television remotes, and optical mice. A matching 950 nm photodiode was also chosen.

Infrared LEDs (IR LEDs) have been aligned to emit 950nm light to photodiodes with a matching peak sensitivity wavelength. This system has been positioned above the food bowl so that when an object interferes with the emitted light a drop in photocurrent can be detected by the system. This input is vital for the proper function of the pet feeder's lid

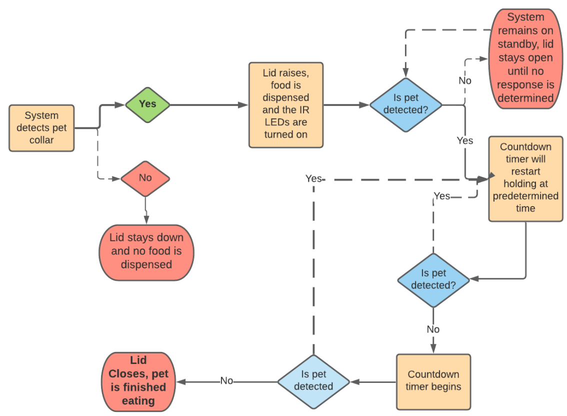

Fig. 4 IR light detection flowchart

2.3.2 DC Motors

The DC motors chosen were both 12 V 40 rpm motors that can apply up to 70 kg.cm of torque. These motors were chosen to be compatible with the L293D motor driver IC that will deliver stable power to the motors when needed. The high torque of these motors also provides the ability to turn the dispenser while there is food stored in the container above the dispenser. One of these motors will be attached to the lid to turn the lid open or shut, while the other motor will be connected to the food dispenser. Since these are DC motors, the direction of spin can be controlled through either software or hardware. This simplistic nature of a DC motor allowed for ease of control of the motors with the microcontroller.

2.3.3 Arduino

The Arduino Uno Rev 3 (using ATmega328P onboard microcontroller) can deliver the hardware level actions that are needed for the pet feeder, such as activating the DC motor when the correct color data is received and turning on and off the lid closing system. This Arduino is capable of serial communication with the Raspberry Pi microprocessor, allowing the Raspberry Pi to instruct the Arduino to dispense food and/or open the lid when the correct color detection data is received by the camera. Additionally, the Arduino's built-in analog to digital converter is used to receive input from the photodiodes that will be utilized to detect whether a pet is eating from the bowl.

2.4 Food Dispenser

The food dispenser must be able to output the correct amount of food (depending on what pet is currently being fed) in at most 60 seconds. The food dispenser uses of gravity to allow the food to fall from the storage container into the bowl. A 3D printed rotating plate (spun by the brushless DC motor), shown in Figure 5 with plastic blades to allow the food to flow from the container down a tube and into the bowl. Due to the controlled nature of the dispensing, the exact amount of food released per wheel rotation can be determined to calculate and program the time it takes to fully dispense a complete meal (using the wheel rpm as a guideline).

Fig. 5 Food Dispenser

2.5 Applications

2.5.1 Web Application

The Opto-Smart Pet Feeder offers a webpage functionality where users can remotely communicate with the device via Wi-Fi. This allows the user to remotely utilize the device to its maximum capability when they are on the go and away from their pets at home.

This Webpage is hosted by the Raspberry Pi 4 system written in python, html, and database files to create a simple yet functional website that are full of script functions to fully optimize the Opto-Smart Pet Feeder's online capabilities.

The Opto-Smart Pet Feeder webpage first introduces the users to either the sign-up page if they are a new user, or to the log-in page if they are a returning user as show in the figure 6 below. The new users must go through an online account registration process providing basic personal information such as an email, and password to create a secure online account associated with the product for users to access the Opto-Smart Pet Feeder functionality safely on the website. The online account registration is a very important part of the remote usage on our website, as the creation of the secure account will rightfully eliminate any hazardous and harmful security risks for all our online users.

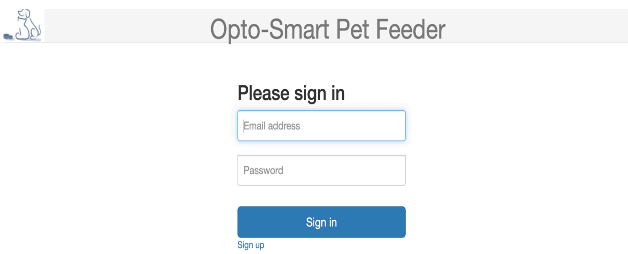

Fig. 6: Sign in page

Once the online account registration process has been finished, the new users and the existing users can now log into their newly created account which will direct them straight into the webpage dashboard as show in figure 7 below that neatly displays all the Opto-Smart Pet Feeder's functionality for the users to fully control.

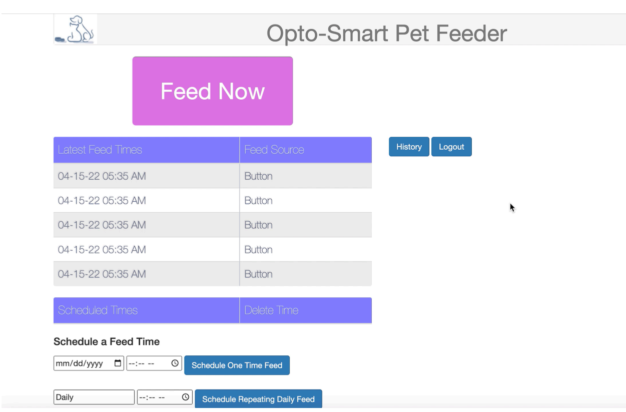

Fig. 7: Home page

Inside of the homepage contains many different dispensing functionalities that is offered to the user. Users may either dispense the pet's food immediately by pressing the "feed now" button, schedule a one-time feeding for the pet by choosing a proper date and time to dispense the food and clicking the "schedule one-time feed" button, or users can schedule a daily dispensing of the food by again choosing the desired date and time to dispense and clicking "schedule repeating daily feed" for the Opto-Smart Pet Feeder to dispense the food to the bowl remotely via the internet through the website.

Users may also click on the history button to view a list of the full history of every dispensing activity done by the pet feeder since the account's creation.

After the user is done using the website, they can logout using the log out button to safely exit out of the program.

III. Exterior Housings

3.1 Bowl Housing

Our housing component was crafted using plywood. The back will be made from acrylic for demonstration purposes so that we can show how the components are situated within the housing. The design is shown below in figure 8.

Fig. 8: Bowl design

Within the housing there are two cut-outs that house the IR LEDs and photodiodes. These allow the light to be blocked when the pet inserts its head to eat as they are located directly above the bowl. The IR LEDs and photodiodes are spaced out to ensure that no matter where the pet eats from the bowl, the system will still detect them.

Fig. 9: IR LED and Photodiodes

3.2 LED Collar Housing

Our LED collar PCB and lens housings were printed using the Lockheed Martin Innovation Lab 3-D printers.

The designs were inspired by Thingiverse designs and edited in Blender. Thingiverse is a website that shares open-source 3-D printable designs. Blender is an open-source software that allows you to edit .stl files and is very useful in editing 3-dimensional printing designs. We were able to modify existing designs to meet our needs. Our lens holder will be fixed upon the collar PCB housing and will then be able to be attached to the pet's collar. In Figure 10, you can see the Collar PCB housing design. The collar PCB housing is designed as two pieces that can tightly fit together, which creates a sturdy housing for our PCB, while also allowing us to open the lid if needed. Using a 3-D printer, allowed us to keep our design lightweight, while also allowing for easy updates and tweaks to our design throughout the engineering process.

Fig. 10: Collar PCB housing design

IV. Testing

4.1 Color Detection

We were able to demonstrate that our color detection system can detect three colors: red, green, and blue. This satisfies one of our design requirements. When searching for a specific color, the system will recognize it and ignore all other colors. Our camera was able to detect all three colors at a distance greater than 10 feet, which greatly exceeds our engineering requirement of detecting at a distance greater than 5 feet.

Once the color was detected from the pets, the Raspberry Pi can trigger the system to open the lid. This is accomplished through a serial communication between the Arduino and Raspberry Pi, in which the Raspberry Pi transmits a digital message to the Arduino microcontroller that indicates to the Arduino that the lid motor must be turned in the correct direction to open the lid.

4.2 IR LED Detection

When testing the IR LED detection system, we measured how fast the photodiodes registered the IR LED signal. After 10 tests, it was shown that our system can detect the signal at an average of 1.588 seconds. Our design specification calls for less than 10 seconds, and this significantly exceeds this expectation.

In another system test, the IR LED and photodiodes were separated a bowls length away from each other (approximately 10 inches) as they would be in our final design. The power of the photodiode in this setup was then measured and noted. This is the normal state of the feeder when a dog is not eating from it. The connection between the photodiode and the IR LED was then interrupted. The power was then again noted. This was repeated a few times to get an accurate power drop. This is what will happen as the dog is eating in the bowl and interrupting the LED signal. This data contains the voltage levels before and after the artificial dog was introduced in between the IR LED and the photodiode, as well as the difference in voltage levels during these two states. The average uninterrupted voltage was 0.401V and the average interrupted voltage was 0.298 V. The average voltage drop was 0.103V for each LED.

4.3 Lid System and Software

Our software to control the lid system was developed using the Arduino IDE. This software initially opens the lid once the Raspberry Pi sends a communication to the Arduino that indicates the correct color LED was detected.

Once the lid is open, the Arduino will continually check if there is a pet blocking the IR LED signal from reaching the photodiodes. When a blockage is sensed, the lid motor will wait 30 seconds after the pet leaves the bowl to turn the lid closed. If the system does not have a pet interrupt the IR LED signal during the 30 seconds, the lid motor will activate and close. During testing, the lid motor closed after an average of 30.714 seconds. This meets our requirements of a lid closing after 30 seconds ± 10 seconds. We were also able to see that if a pet re-entered the bowl, the lid would start a new countdown to ensure that the lid would not close on the pet.

4.4 Food Dispenser

The food dispensing system was able to correctly dispense an approximately equal amount of food every time the dispenser motor was activated by the user. Initially some of the pet food would occasionally become stuck in the dispensing mechanism when the dispenser motor became activated. To fix this issue, the dispenser's connection to the motor had to be strengthened and the motor needed to be turned for a longer duration of time.

4.5 Online Application

We were able to test our online application several times by making sure that the system will function in the correct manner when the user is utilizing our online webpage via Wi-Fi.

We were able to make sure the sign in user account validation was all properly set and implemented to the online application to avoid faulty validation for invalid account/ functionality access. This testing process was completed by inputting multiple incorrect user identification and password to check and see if we were able to sign into our application or not using the false ID.

The sign-up system was tested by creating valid accounts and assuring that the system would allow the user to log into the correct account.

We were able to ensure that all our dispensing functionality of our webpage were fully operational by testing each digitally embedded button. We discovered that by clicking the "Feed Now" button the pet food was dispensed in approximately 1.0 second. This similarly was operational with the other two "schedule one-time feed" and "schedule repeating daily feed" buttons. Every time that we used these functions, the history webpage updated with the appropriate data.

V. Results

Throughout the testing of our device, were able to test four of our engineering specifications, all of which exceeded our minimum requirements. This included developing working code for the camera to detect the colors being displayed from the LEDs at a distance greater than 5 feet, with a very fast response time when detecting the colors (<0.5 seconds). We also saw great success with our IR LED system by detecting a significant drop in voltage across the photodiodes when the IR LEDs were being blocked by an object. The average time it takes for the system to detect when an object has blocked (or stopped blocking) the IR LED signal was approximately 1.59 seconds, which greatly exceeds our design specification of a response time less than 10 seconds. The lid closing system also met all the engineering specifications required. Once a pet is finished eating (no longer blocking the IR LED signal), the lid will wait 30 seconds, check if a pet is blocking the IR LED signal, and then proceed to close. According to our testing, the average time it took the lid to close once a pet was finished eating was 30.714 seconds. This value falls well within our desired threshold of 30 seconds ± 10 seconds. Another notable specification that was achieved is a dispensing time of less than 60 seconds. All the demonstratable engineering specifications for the Opto-Smart Pet Feeder have been thoroughly evaluated and confirmed to have successfully met the proposed requirements.

VI. Conclusion

Overall, the project was successful in meeting our goals and design specifications. The combination of optics and electronics has allowed for a system design that enhances user efficiency using simple, yet powerful techniques.

Biographies

Tyler Knight is a senior at the University of Central Florida and will graduate with a Bachelor of Science in Photonic Science and Engineering. He has work experience in optics and photonics focusing primarily with optical systems integrated with liquid crystal. After graduation, Tyler plans to continue working in industry as an Optical Engineer specializing in research and development.

Cassidy Coll is a senior at the University of Central Florida and will graduate with a Bachelor of Science in Photonic Science and Engineering. She has intern experience in both optics and photonics, as well as systems engineering. After graduation she plans to work as a Systems Engineer at Lockheed Martin in Orlando, Florida.

Jacob Haas is a senior at the University of Central Florida and will graduate with a Bachelor of Science in Electrical Engineering. After graduation, Jacob plans on pursuing a working career in the Electrical Engineering profession before continuing in further education.

Ricky Egawa is a senior at the University of Central Florida and will graduate with a Bachelor of Science in Computer Engineering. He has intern experience in systems engineering. After graduation he plans to work as an Electric Optical Engineer at Lockheed Martin in Orlando, Florida.

ACKNOWLEDGEMENT

This project could not be completed without the assistance and guidance from Mr. David Gross with his help in advising and the building of the main enclosure of the Opto-Smart pet feeder, Dr. Justin Sigley for his help in troubleshooting of our collar tag PCB and getting it to work the way it should.

We would also like to thank our committee members Dr. MJ Soileau, Dr. Marwan Simaan, and Mr. Daniel Miller for taking the time to review our project. We would also like to take this time to thank Dr. Lei Wei and Dr. Kar for their informative guidance throughout this entire process.

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